Advanced Solar Simulator Technology Plays an Essential Role in Supporting NASA's Artemis Program

How programmable LED solar simulator (pLEDss) technology ensures the performance of the advanced solar cells necessary for deep space applications.

By Casey Hare, CTO, Angstrom Designs Inc.

NASA's Artemis program consists of a series of missions designed to land humans on the Moon and establish a sustainable, continuing presence. A long-term foothold on the Moon's surface enables invaluable research and testing opportunities that will set the stage for future groundbreaking missions — including the first human mission to Mars.

A critical element of the Artemis program is to launch and construct Gateway — humanity's first Moon-orbiting space station. An intermediary outpost for lunar travel, Gateway will consist of multiple modules pieced together, each providing essential facilities to support Artemis missions.

Two modules — the Habitation and Logistics Outpost (HALO) and the Power and Propulsion Element (PPE) — will comprise the foundation of Gateway. When ready, HALO and PPE will launch together from Earth to begin lunar outpost construction. Gateway's capabilities will be expanded with additional modules provided by the European Space Agency, Canadian Space Agency and Japan Aerospace Exploration Agency — all of which will be powered by PPE.

The PPE module will function as Gateway's power plant by supplying 60 kW of power to Gateway's solar electric propulsion system and various other subsystems. To meet NASA's power, mass and radiation resistance requirements, PPE is designed with advanced solar cell technologies — highly efficient, multi-junction solar cells.

While manufacturing advances have enabled the creation of these sophisticated cells, legacy testing capabilities did not keep pace with the improvements in solar cell technology. It is important to ensure that cell performance meets NASA's criteria. Programmable LED solar simulator (pLEDss) technology is an innovative testing capability that delivers the necessary performance to qualify the PPE module's advanced solar cells.

Here is an overview of multi-junction solar cell technology along with some of the reasons why pLEDss is the right technology to support PPE and the Artemis program.

Multi-Junction Cell Technology Enables Modern and Future Solar Power Generation

Multi-junction solar cells essentially consist of multiple solar cells stacked on top of each other to capture a broader range of solar energy. A multi-junction cell can harness a wider range of the solar spectrum because the constituent cells each feature different bandgaps that are optimized for different ranges of the spectrum. This cell design harnesses a greater portion of incident sunlight and ultimately improves efficiency.

Advanced space applications like the PPE module call for more advanced solar cell designs with upwards of three junctions per cell. Because of their increased efficiency, three-junction cells and above are much more effective for space applications. Greater efficiency allows NASA to specify lighter spacecraft designs that feature more compact solar arrays or to push the limits of solar power in space. This weight reduction directly benefits rocket payloads, where every kilogram saved counts.

The PPE module is constructed with multi-junction solar arrays because of their advanced performance, light weight and excellent radiation resistance. But while multi-junction designs are more efficient than their conventional counterparts, they are also more challenging to test.

Solar Cell Basics

A standard solar cell is essentially a flat diode specifically designed to absorb sunlight and convert the electromagnetic radiation into electricity via the photovoltaic (PV) effect. Depending on a cell's design, different types of solar cells will capture different ranges of the solar spectrum.

When photons enter the solar cell, the photons transfer energy to the electrons within the semiconductor material and excite them to higher energy states. This energy increase only occurs if the incoming photons have enough energy to overcome the semiconductor's bandgap — an energy threshold based on material properties and design. Photons with lower energy than a material's bandgap are not collected and used for power generation.

Multi-Junction Solar Cells for Space

Most solar cells on earth have a single diode, or junction, to convert photons to electrons. For terrestrial solar, where there are lots of available rooftops or open areas, this is a good solution. For space missions where solar panels must be launched on rockets and deployed on complex mechanisms, active solar panel areas are at a premium. For most space applications, more power per area is needed than single junction solar cells can provide, so three-junction (3J) solar cells have been the state of practice for the last few decades. For NASA's Gateway PPE solar panels, NASA demands the latest multi-junction cell technology to meet its ambitious needs.

The Challenges of Testing Multi-Junction Solar Cells

Solar simulators ensure solar cells operate correctly by replicating the power production under sunlight spectra and intensity. Traditional solar simulation methods like Xenon flash lamps are adequate for simple solar cell designs, but they perform progressively worse when applied to cells with three junctions and more. Multi-junction cell designs are more complex which prohibits testing them with the same conventional methods.

Because multi-junction cells consist of multiple layers, each optimized for different spectra, a solar simulator's light output must be adjustable and capable of matching the spectrum and intensity that each junction was designed for. Traditional Xenon flash lamps do not have this level of flexibility beyond two or three junctions.

Traditional solar simulation technologies like Xenon flash lamps have poor spatial non-uniformity across large areas. These far-field simulators also take up a great deal of space on the manufacturing floor as the lamps must be placed away from the test article. Since PPE's solar arrays are about the size of a football field's end zone, utilizing Xenon flash lamps would introduce a great amount of complexity.

PPE is pushing the limits of power generation to deliver the maximum capability to Gateway. Any increase in spatial non-uniformity translates into a decreased understanding of solar array capability and a decrease in usable power on orbit. Additionally, due to the large size of the PPE solar arrays, any testing configuration that forces an even larger facility will increase costs.

This is where LED simulation comes into play.

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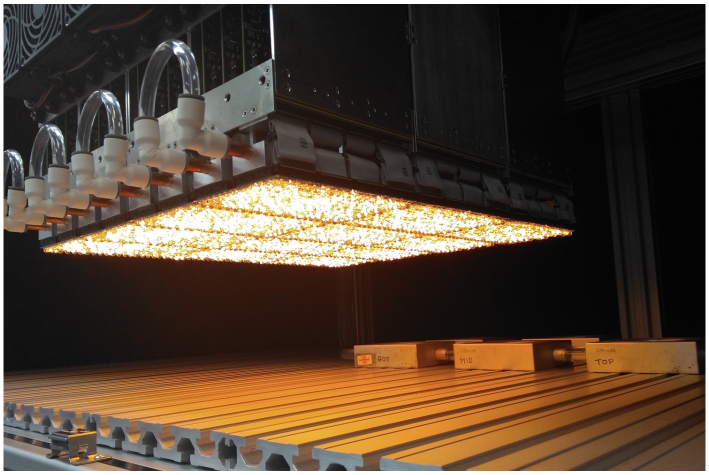


LED-based technologies enable a near-field solar simulator where hundreds or thousands of individually adjustable LEDs are placed close to the solar cells.

How pLEDss Enables Sophisticated Testing

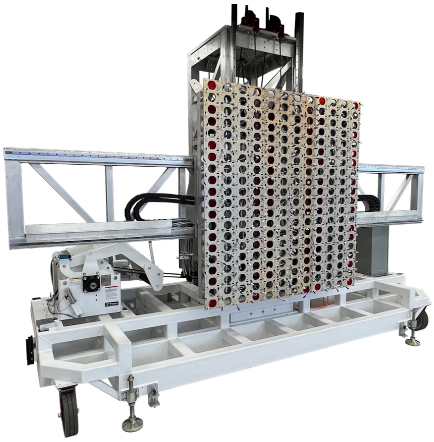
Programmable LED solar simulators are the next generation of solar simulation systems, leveraging advanced LED lights and control technologies. These LED-based systems deliver greater performance when mimicking solar panel output under the sun's light. Additionally, this technology is extremely flexible and capable of addressing a wide range of solar cell technologies both current and future. Programmable LED solar simulator technology has already measured solar cells with three, four, five and even six junctions.

Solar simulators like pLEDss can individually control each LED light which allows engineers to apply enhanced tests using both spectral and spatial non-uniformities. Controlling spatial non-uniformities provides deep insight into the cell's health, such as information on potential hotspots, manufacturing defects and efficiency.

For example, manufacturing defects in a solar cell can generate different currents at each junction. With traditional solar simulator systems, it is impossible to measure these current differences after cells have been assembled into strings. However, pLEDss technology can measure the current at each junction in every cell to find the defects — even in an assembled string.

A key feature of the patented pLEDss design is the capability to individually adjust the intensity of light applied to both individual solar cells and their junctions. Fine-tuning this control ensures performance and efficiency. The high level of both spatial and spectral control allows an LED solar simulator to test and calibrate a wide range of solar cell technologies with different spectra profiles according to specific application requirements.

This technology is automated — saving NASA significant time and resources. Automation also delivers improved measurement accuracy, repeatability and speed. Additionally, pLEDss can test solar cells in a very small area with extreme accuracy — enabling NASA to hone in on the health of PPE's arrays — right down to the individual junctions.



A subassembly of the pLEDss solar simulator frame that will test NASA's PPE panels.

Flexible pLEDss Technology Is Ready for Future Cells

Today, five-junction (5J) solar cells are flying their first missions and six-junction (6J) designs are in development. It is only a matter of time before these sophisticated cells are regularly used in spacecraft design. Programmable LED solar simulator technology was designed to address the challenges of multi-junction cells — no matter how many junctions. This ensures that pLEDss will meet the needs of spacecraft using the advanced solar cells of the future.

Learn more at [www.angstromdesigns.com.](http://www.angstromdesigns.com)

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